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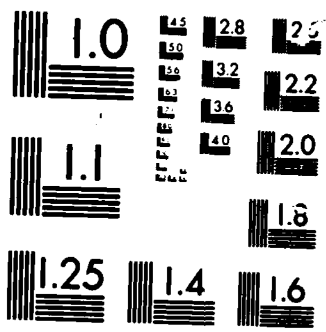

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AFOSR-TR- 86-0052

DEVELOPMENT OF LOW-ENERGY X-RAY SPECTROGRAPH SYSTEM

Final Technical Report

for the

DOD/University Instrumentation Grant

AFOSR Grant 83-0222

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Presented here is the final technical report for the DOD/University Instrumentation Grant, AFOSR-83-0222. It describes the design and construction of a "state of the art," large aperture focussing spectrograph of the Johann/Johannson geometry, specially developed for the low-energy x-ray region of 50-5000 eV. The spectrographic system includes (1) a four kilowatt, demountable low voltage x-ray excitation source, (2) a three-position holder for samples which are closely coupled to the excitation source and with a variable take-off angle, (3) a stepping motor driven scanner which accomodates large aperture curved crystal analyzers, a 10" diameter focussing circle, and an automatically adjusted exit slit that provides a constant solid angle of measured radiation from the same sample area and at the same take-off angle for
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all Bragg angles, (4) a "tunable" gas flow, sub-atmospheric pressure counter, and finally (5) provisions for a rapid and easy interchange of thin window filter mounts for both the x-ray source and for the counter. A small computer has been specially interfaced to provides scan control, data acquisition and presentation, and preliminary data analysis. It is connected to a large computer for programmed resolution enhancement, de-convolution and the determination of absolute radiative yields from the experimental, overlapping atomic or molecular orbital spectral components.

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I. INTRODUCTION

In 1983, this principal investigator received a DOD/University Instrumentation grant (of amount $58,600) to develop a "state of the art" curved crystal, high resolution focussing spectrograph system for atomic and molecular spectroscopy in the low energy x-ray region of 50-5000 eV. By mid-1984 this new spectrographic system was completed at the University of Hawaii and immediately became an important and much needed complement to the x-ray and electron spectrographic systems that had already been developed on this long-standing AFOSR program, the Development and Application of Low Energy X-Ray Physics and Technology (current AFOSR Grant, No. ISS4-85-00011). In December, 1984 this AFOSR program, with its laboratory and staff, as transferred to the University of California's Lawrence Berkeley Laboratory as part of the new and first U.S. Center for X-Ray Optics. The lay-out and photos of our laboratory which has been specially constructed at LBL for this AFOSR program are presented in the Appendix showing in the foreground, Spectrographic System No. 3, which has been developed under this DOD Instrumentation grant and is reported here.

II. DESCRIPTION OF THE NEW SPECTROGRAPHIC SYSTEM

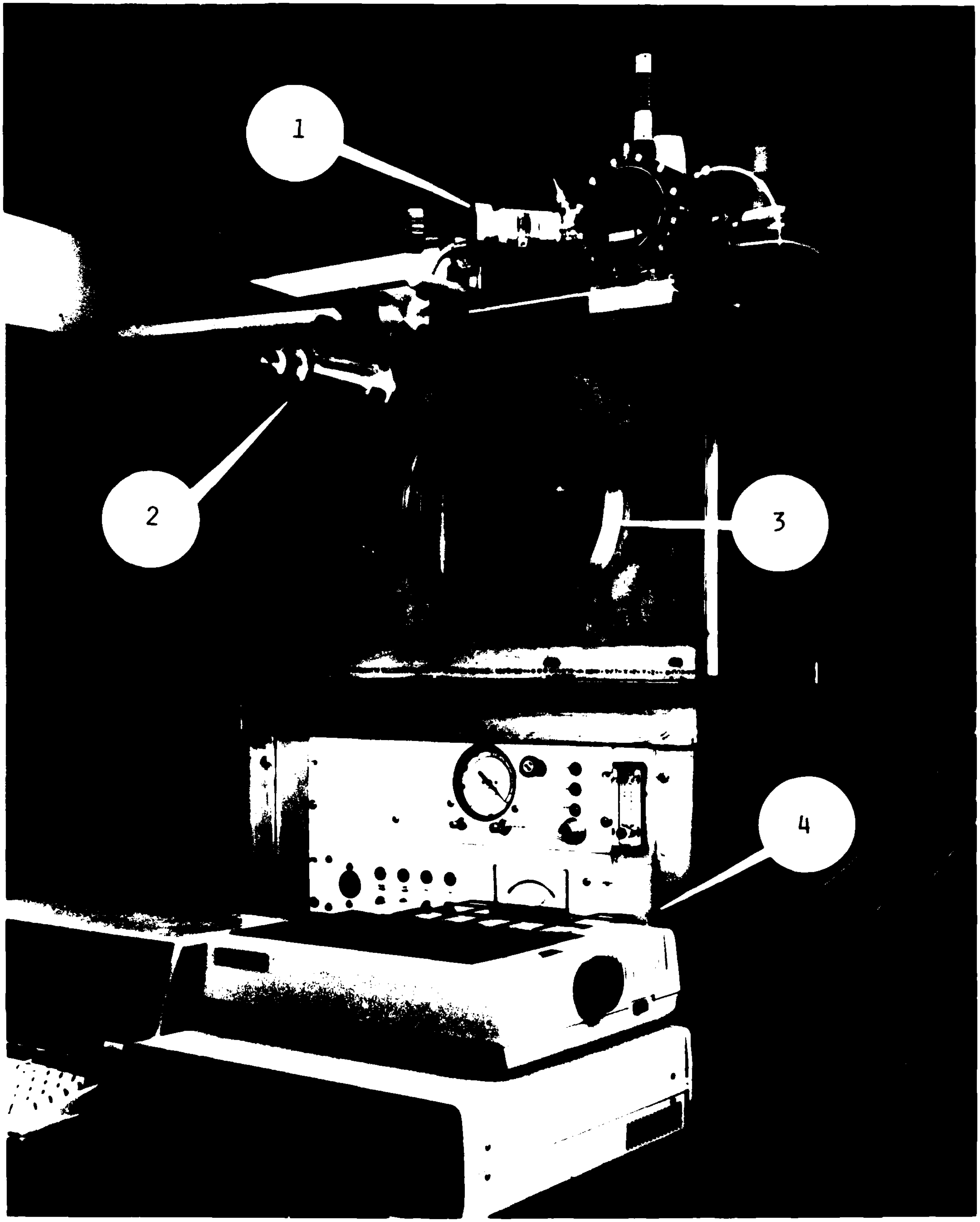
A larger view of the new spectrograph is shown in Fig. 1. Its design features may be summarized as follows:

(1) A four kilowatt demountable x-ray excitation source (Henke type) with interchangeable anodes that provide strong characteristic line excitation radiations of photon energies chosen to be just above the ionization energies of the spectral series to be studied (for optimum excitation efficiency). The x-ray source and its appendage Vacion pump may be tilted upward, via rear hinges, through a 90 degrees rotation to allow rapid and easy replacement of the thin filter windows that are mounted onto a vacuum isolation gate on the x-ray source. In operation the tube housing O-ring seals onto the stainless steel spectrograph housing.

(2) A three-position sample holder (for 1 1/4" sample disks) slides beneath the excitation source within about one inch of the excitation anode surface. A vacuum feedthrough sliding shaft translates, with detents, to position the samples and also rotates to orient the sample for the optimum take-off angle of the measured fluorescent radiation (The measured radiation direction is about 90 degrees to the mean direction of the excitation beam in order to minimize coherent scattered radiation background.)

(3) The recently refined Bausch and Lomb, Johann-Johannson curved focussing crystal scanner has been adopted here. It has proven to be an excellent scanner as applied for many years on the B & L conventional x-ray fluorescence analysis spectrographs. With this mechanism, the crystal is translated, using a precision lead-screw mounted horizontally along a line that intersects the sample and is driven by a stepping motor. The crystal thus always analyzes the radiation from the same sample region and at the same take-off angle (as Bragg angles are scanned). A sub-atmospheric, thin window gas flow proportional counter translates along a 10" diameter focussing circle which itself rotates about the point of tangency of the crystal as a spectrum is scanned. A variable exit near the proportional counter automatically opens as the crystal translates away from the sample (to larger Bragg angles) to provide a constant solid angle for the measured radiation.

(4) A small computer (Hewlett-Packard 87A), digital plotter and printer are specially interfaced to this spectrograph for scan control, programmed data acquisition and presentation, and for preliminary data analysis. This computer is directly connected to one of LBL's large VAX computers for the mutli-variable fitting and de-convolution programs that have been designed for resolution enhancement and for the determination of the absolute radiation yields of the components of the overlapping spectral lines. (1,2)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III. THE APPLICATION PROGRAM

This spectrographic system has recently been made operational at our new AFOSR laboratory at LBL. We would like to describe briefly here the program for its first applications:

Primarily, this spectrograph has been designed for the development of fast atomic and molecular spectroscopy in the 50-5000 eV low-energy x-ray region. There is a critical need at this time for large-aperture spectrometry in applications for which the numbers of photons available for high resolution measurement are relatively small. These includes, for example, measurements upon samples that chemically change under the excitation dosages that are required for conventional x-ray spectroscopy (for which fast spectroscopy instead of higher excitation levels are essential). Other examples of applications that demand fast spectroscopy are those with the modern, intense, sharply pulsed x-ray sources (e.g. of synchrotron or laser-produced high temperature plasma pulsed radiations) for time-resolved spectroscopy into the picosecond range (3) (for which again the number of photons available for precise time-resolved measurement are often limited). High temporal resolution with the short pulse excitation is needed for such spectroscopic analysis in fusion energy research, x-ray laser development, for time-resolved radiation damage studies, and for studying systems (as biological samples) in effectively their normal state before significant radiation damage occurs.

In the instrument described here a large aperture is obtained by using curved, focussing crystals of either the Johann or the Johanson geometry. The crystal systems that we have typically used for the 100-10,000 eV region have been described in (4). For the lower photon energies, below 500 eV, we are applying the Langmuir-Blodgett multilayers (lead salts of straight-chain fatty acids) and sputtered high/low density multilayers which are being developed and characterized in this laboratory (5).

In the present instrument the photons are collected along the total line focus region at a slit of a "tuned" sub-atmospheric proportional counter. By opening up the entrance slit of the spectrograph and utilizing directly the full irradiated area of the sample, an entire spectral band can be simultaneously presented along the focussing circle. Along an arc of this circle it is planned next to establish a curved, two-dimensional position-sensitive electronic detection. In this way the photons within the entire spectral line width and for an extended spectral series (e.g. for a molecular orbital band spectrum) can be simultaneously measured thereby further increasing the spead of measurement.

Johann, cylindrically curved multilayers and two-dimensional electronic, time-resolving, position-sensitive detectors are considered to be among the most important elements that are needed for fast, modern x-ray diagnostics. We are planning to apply the spectrographic system described here for the development of these elements for new specially designed spectrographs to be applied to the important group of applications that have been described above.

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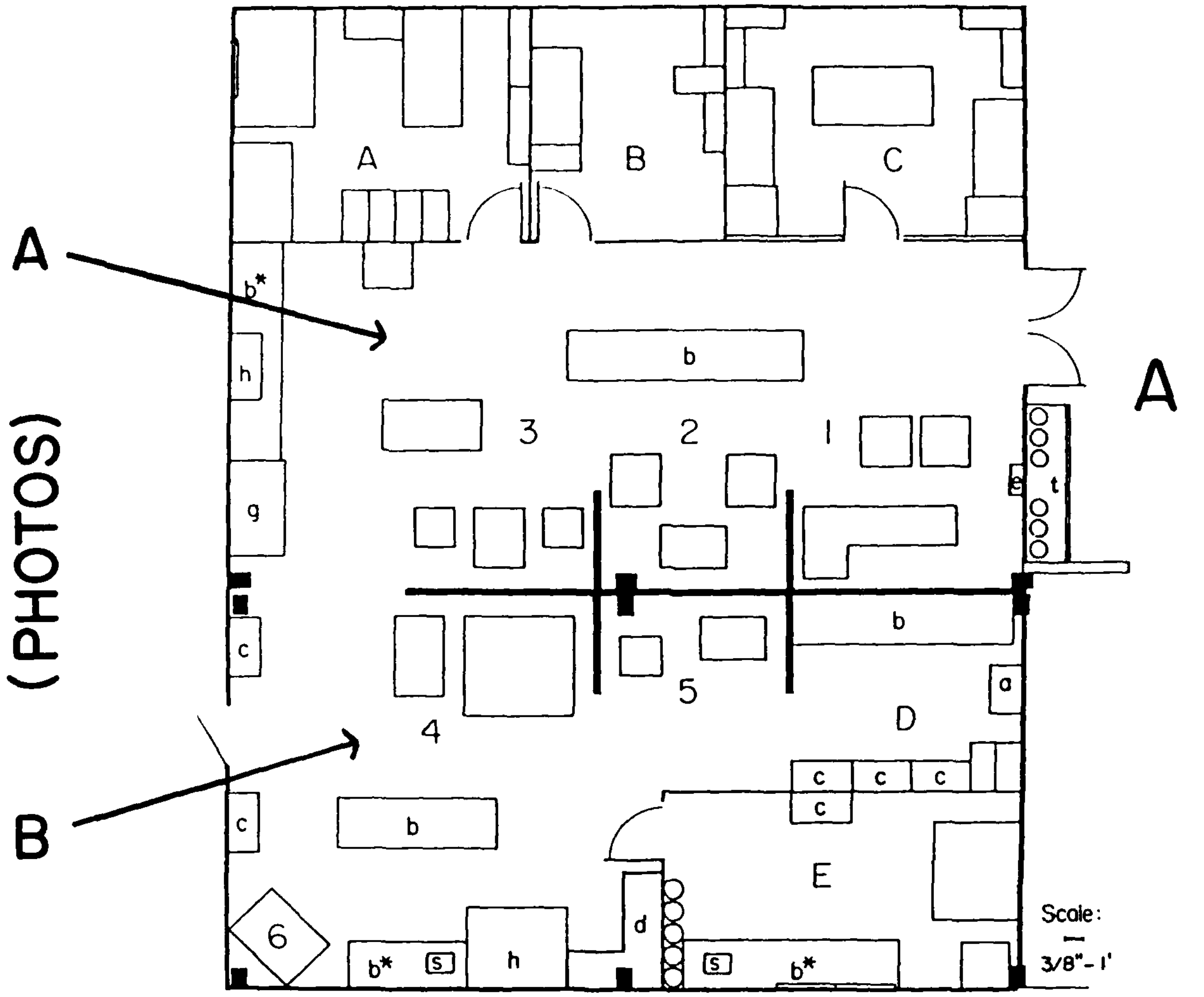
LOW-ENERGY X-RAY AND ELECTRON ANALYSIS LABORATORY

of the

LBL CENTER FOR X-RAY OPTICS



A. Administrative; drafting, word processing, manuscript preparation; project library, catalogs, reprints.

B. Office--BLH

C. Mini-computer experimental data handling, plotting; library of data files, programs; conference.

D. Electronics construction and maintenance; optical and electronic measurement instruments; supplies.

E. Construction of molecular multilayers for low-energy x-ray analyzers; thin film, high resolution photoresists.

B

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1. Flat crystal scanning spectroscopy; multilayer characterization, absolute crystal reflectivity measurements; molecular and solid state spectroscopy.

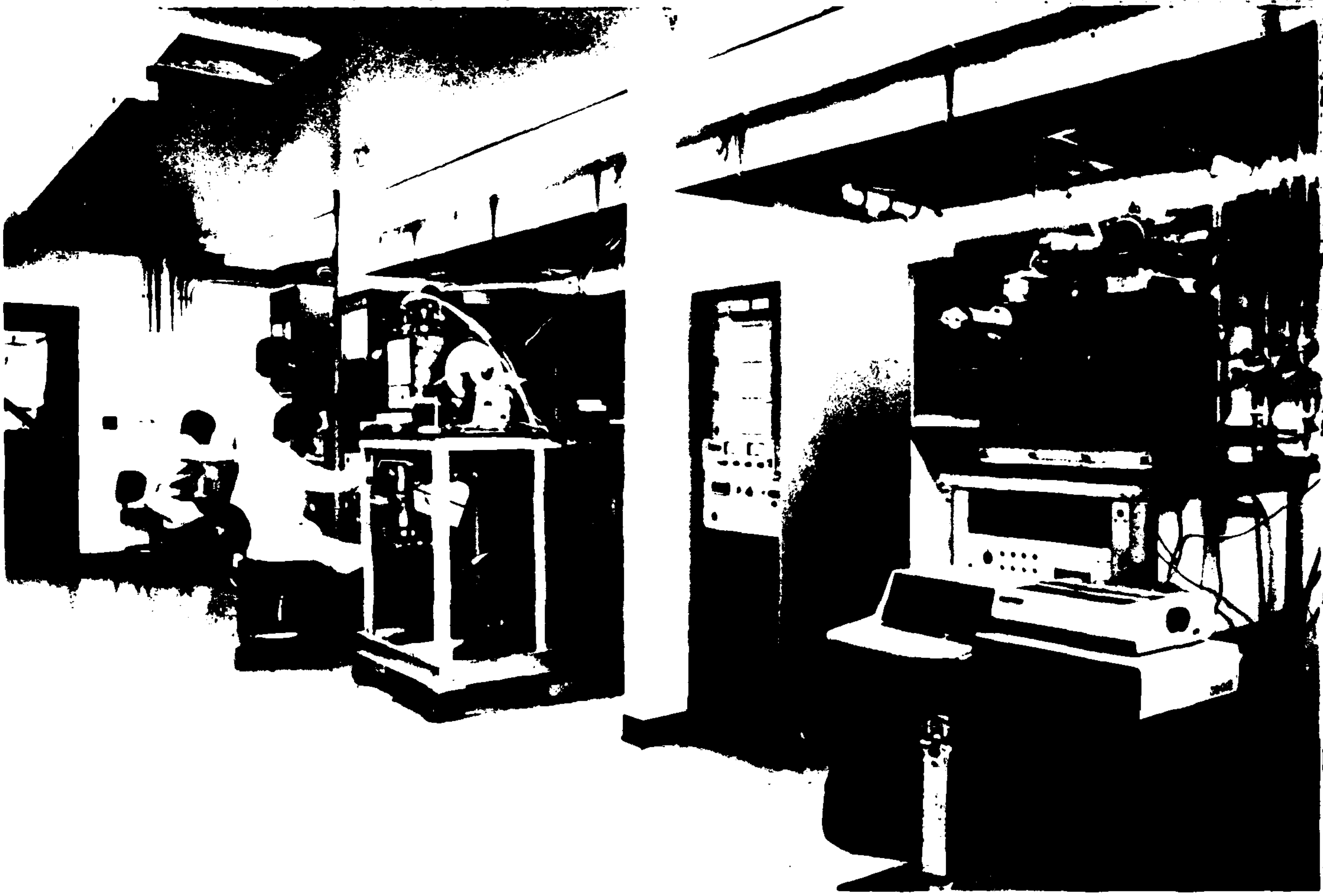
2. Fixed analyzer spectroscopy; absolute calibration of elliptical analyzers, mirror monochromators.

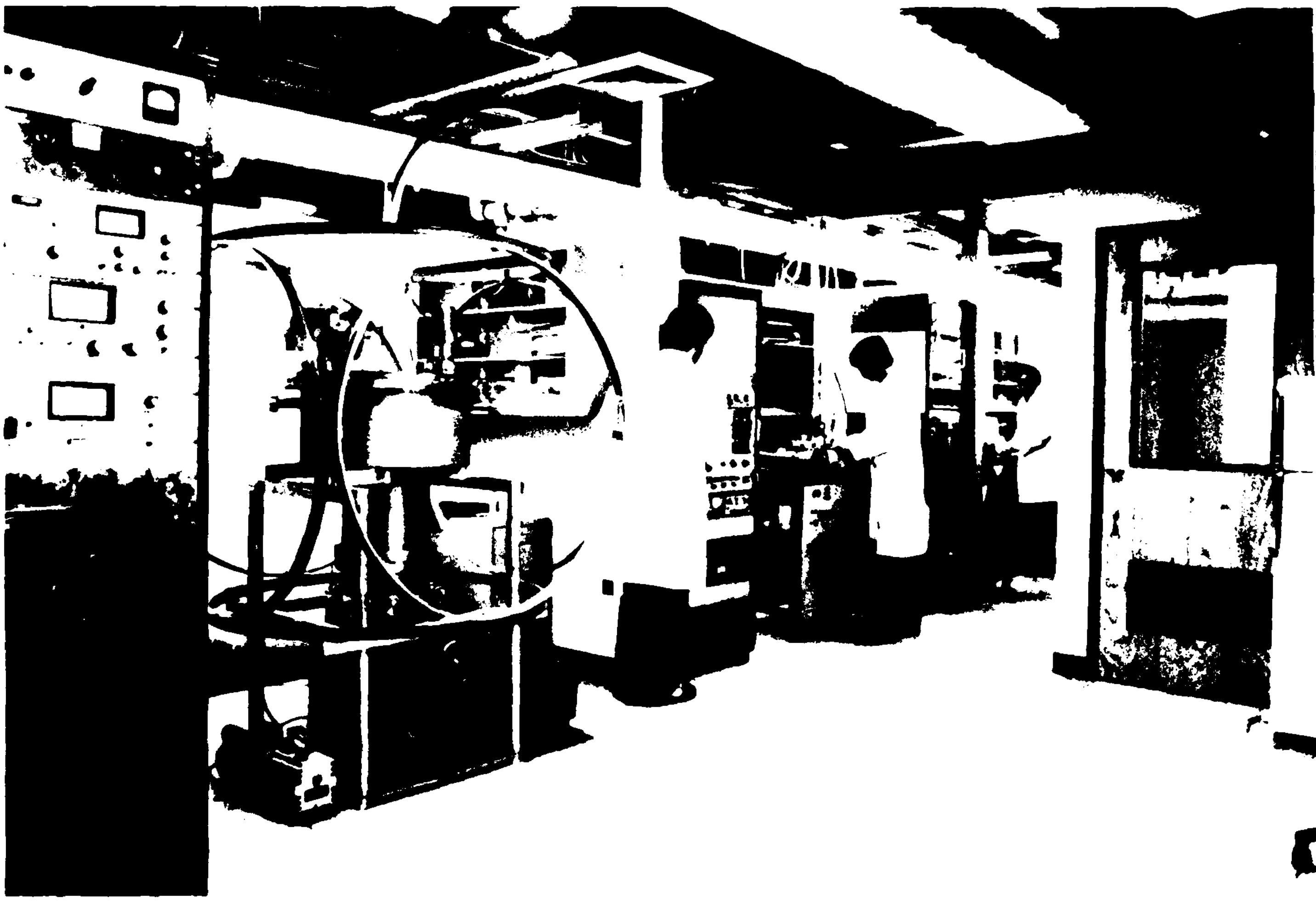
3. Curved crystal scanning, high sensitivity spectroscopy; evaluation of position sensitive detectors; "fast" spectroscopy for time-resolved measurements, radiation damage studies.

4. High sensitivity electron spectrograph (20", precision hemispherical analyzer); XPS, secondary electron energy distributions from x-ray photocathodes.

5. Absolute calibrated x-ray source facility (filtered fluorescent sources, photon-counting proportional counter monitor); photocathode quantum yield measurements; photoelectric detector and photographic film calibration.

6. Vacuum evaporation and sputtering, fabrication of thin films, x-ray mirrors, low/high density CsI photocathodes, etc.





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